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Original Research

Investigation and Evaluation of Green Waste Composting Parameters

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Abstract

With the growth in the living standard of the European population, increasing amounts of waste are accumulating. Waste poses a threat not only to the environment, but to human health as well. The major part of waste consists of organic waste, including a fair amount of green waste; therefore, composting should play a role as important as possible in the integrated system of waste. Certainly, composting will not help deal with all the problems of waste, but this could be an integral part of the municipal waste management strategy.

During the experiment the green waste of different compositions was analyzed: leaves, grass, and crushed wood. Green waste mixtures of several types were formed. In the course of the experiment, concentrations of methane emissions were determined and the influence of crushed wood on the formation of methane quantity was evaluated.

Keywords: green waste, biogas, methane, composting

Introduction

The treatment and reuse of organic waste is a priority of environmental policy in different countries [1, 2]. The utilization of organic waste is also emphasized in EU directives (Directive Nos. 99/31E/EC and 86/278/EEC) [3, 4].

As European society grown wealthier it creates more and more waste. Every year the European Union produces over 2 billion tons of waste, including 200 million tons of municipal waste [5]. According to the European Commission, in the last six years the quantity of waste has increased more than 10 per cent. Huge amounts of waste pose a threat not only to the environment but to human health, and one should not forget that waste handling becomes increasingly expensive [6].

Prioritization of waste storage alone will not solve the issue. Therefore, a wider approach to waste management in the aspects of social and economic development and resource management is necessary. The key prerequisite for efficient waste management is overall reduction of waste [7, 8].

Three main methods of managing collected waste are used in global practice: waste recycling or composting, waste incineration, and waste disposal in landfills. The last method is the most widely spread and the cheapest. However, waste disposal and storage at landfills poses a big threat to the environment [9].

Legally operating dump sites are approaching the limits of their capacity, emit toxic or explosive gases into the atmosphere, and discharge compounds of heavy metals and other toxins into the soil and ground waters. And it is impossible to measure the threat posed by illegal dumps [10].

The main factors having an adverse effect on the environment are landfill gases and leachate. Leachate forms when precipitation and other liquids migrate through the layer of the waste. It is a concentrated pollutant and if it gets into the soil without any control it can pollute ground waters.

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Landfill gases form when microorganisms biodegrade organic waste in the anaerobic environment. Large amounts of biogases, whose major part consists of methane, accumulate in all landfills [11-14].

Both methane and carbon dioxide gases cause the greenhouse effect. Attention should be paid to the fact that methane stimulates the greenhouse effect 21 times more intensely than carbon dioxide. Consequently, landfill gases emitted to the atmosphere harm the environment – increasing the greenhouse effect and causing explosions and fires, harming plants and posing threats to human health [15].

The process of biodegradation of organic compounds results in gas emissions containing methane, carbon dioxide, hydrogen, and hydrogen sulphide. Apart from that, the mixed biodegradable waste getting into the soil as fertilizer often contains inorganic compounds that unfavourably affect the soil structure and may have an adverse effect on fertility, while pathogens pose threats to human and animal health. In addition, there is a big threat of surface and ground water pollution. Therefore, when treating organic waste the focus is laid on ecological problems and electric and thermal power are additionally produced [16, 17].

Composting may considerably reduce the amounts of municipal waste that are presently directed to incineration facilities and landfills [18, 19]. Composting is the keystone of sustainable development but, unfortunately, it is often not applied in a system of municipal waste [20]. The amounts of accumulated organic waste are steadily increasing in the world so that it is necessary to apply an environmentally friendly method. Certainly, composting will not solve all the issues related to waste, but it could be an integral part of a municipal waste management strategy [21].

Even 50 percent of total waste amounts can be composted. Of them, municipal waste accounts for even 33 percent. And all this accumulates due to the fact that in many countries people do not sort waste [22].

The aim of this study is, when dealing with the problem of organic waste, to determine the concentration of methane that is emitted during the biodegradation process of the green waste of different compositions, as well as its change in time with the change of temperature, and to evaluate the percentage influence of crushed wood on the formation of methane amounts.

Experimental Procedures

The main substance generated during the process of composting is methane. Therefore, during the experimental period quantities of the following biogases' constituent substances were measured: methane (CH_4), and oxygen (O_2), and pH values. The correlation and dependences between the quantities of these substances and conditions of biogas formation were determined.

Temperature is an important parameter when evaluating the conditions of biodegradation. It has one of the greatest influences on the formation of biogases.

Three types of waste were analyzed: grass, leaves, crushed coniferous branches (assumed as 100% of crushed wood), four types of mixed waste consisting of leaves and grass (50:50); leaves and grass (45:45) and 10% crushed wood; leaves and grass (35.5:35.5) and 25% crushed wood; leaves and grass (25:25) and 50% of crushed wood. All the listed types of mixed waste refer to ratios of dry mater. Leaves, grass and crushed wood were collected for the experiments without impurities. Before the experiment mechanical shredding was used for all types of waste because the particle size reduction increases the specific surface area of the waste particles and decreases the particle size distribution. After shredding, the organics were in the <40 mm fraction.

With the aim of forming anaerobic conditions, the samples of each type of wood were placed in hermetic reservoirs of 50 l capacity each. The weight of the substrate was selected so that when these reservoirs are practically filled, some space is left for the accumulation of biogases. To speed up the process of composting green waste, it was moistened with an identical amount of water – 1.2 l.

The experiments were performed in a room whose conditions were similar to those of the natural environment.

a) b)

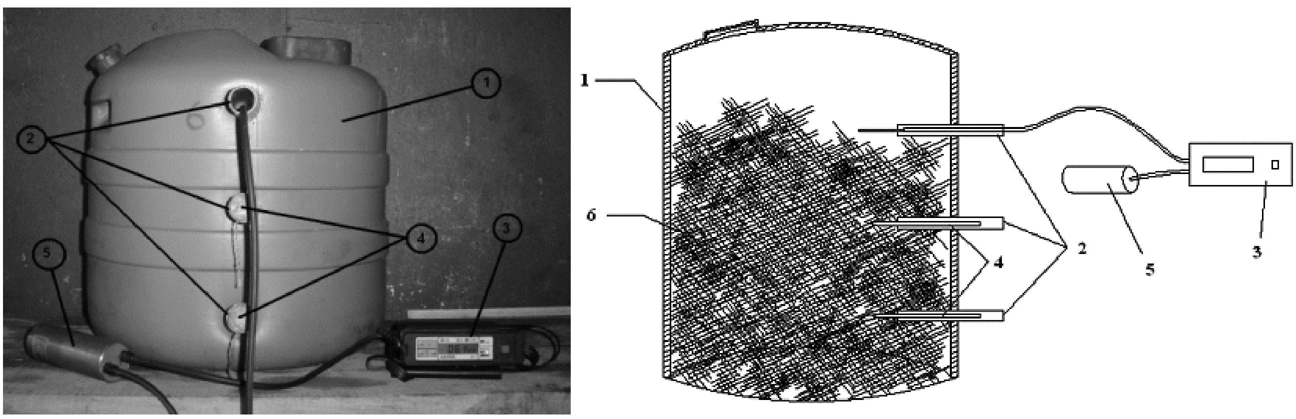

Fig. 1. Scheme of experimental research equipment: a) front view, b) longitudinal section of the scheme. 1 – reservoir with green waste capacity of 50 litres, 2 – biogases collection probes, 3 – gas analyzer GD/MTG-7, 4 – thermometers, 5 – gas taking pump, 6 – green waste.

The scheme of the experimental research equipment and the longitudinal section are given in Figs. 1a and b.

The following devices and reservoirs were used during the experiment: hermetic vessels of 50 l capacity, thermometers, pH-meter WTW, and metering device GD/MTG – 7 (metering range/capacity: oxygen – 0-25%/0.1%, methane – 0-40%/1%, hydrogen sulphide – 0-50 ppm/0.1 ppm).

The whole experiment was divided into 3 main stages. The 1st experimental stage was the observation of the anaerobic biodegradation process of two samples containing no admixtures of grass and leaves separately (reservoirs 1 and 2). The 2nd experimental stage was the observation of the grass and leaf waste mixture (50:50), and crushed coniferous branches (reservoirs 3-7). The 3rd experimental stage involved 10, 25, and 50 percent of crushed wood waste blended into the leaves and grass mixture, respectively (reservoirs 4, 5, and 6).

The measurements were taken after 4 days from the preparation of the organic waste mixtures, since this is waste of organic origin and the process of its composting starts rather quickly. When the emissions of biogases started, measurements were taken every 2 days. The experiment lasted until the day when significant decreases in the amounts of biogases were recorded. The total period of experiments amounted to 60 days.

During this experiment, the concentrations of methane and oxygen, fluctuations in pH values and changes in internal temperatures of waste were determined. The comparison of the curves whose research is rational was made.

Discussion of Results

The main and most useful product of composting is methane, therefore major attention was devoted to its formation. The amount of methane depends on several parameters but it is mainly influenced by waste type and temperature, and the composition of admixtures.

The crushed grass waste was distinguished by the highest concentrations of methane during this research. It reached the maximum on the 43rd day of measurements and was 19.2% (123 g/m^3), even though it approached the maximal value on the 9th day of measurements (18.8% (120.5 g/m^3)). These highest concentrations of methane in the grass waste were achieved due to the fact that grass had one of the highest internal temperatures and contained large amounts of nutrients (nitrogen) and tolerated mesophilic bacteria. On the 60th day of measurement the concentration of methane in grass fell to 9.9% (66 g/m^3). The lowest concentrations of methane were recorded in the mixture of grass and leaves (50:50). The highest concentration of methane in this waste hardly reached 8.7% (54.7 g/m^3) on the 9th day of measurement, and later it gradually decreased and fell to 1.6% (10.7 g/m^3) at the end of measurement. All this can be explained by the fact that the mixed waste of leaves and grass was dominated by a large ratio of carbon, which slowed down the growth of microorganisms and impeded the release of methane. The waste was composed of the mixture of grass and leaves and the admixture of 10% of crushed wood waste was distinguished by the highest variations in methane concentration (from 4.6% (32.7 g/m^3) to 18.2% (117.8 g/m^3)). In the grass and leaf waste with certain amounts of crushed wood blended in, the highest concentrations of methane were in the waste containing 10% of crushed wood, the lowest – 25% of crushed wood. During certain days (7, 11, 15-23), the waste of grass and leaves containing 10% of crushed wood showed the highest concentrations of methane compared to total green waste. It should be noted that wood is composed of a long and complex chemical compound and microorganisms need a longer period of time to degrade it (Fig. 2).

After the comparison of another author's [23] tendency of methane release in other biodegradable waste (fruit and vegetables), it can be stated that the amount of methane is rather similar at the beginning of the experiment when it reached 7.4% [23], in the meantime, during this experiment it fluctuated in the range of 6.1% and 10.2%, depending on the type of waste. At the end of the experiment the data was quite different: in the author's case, the methane concentration of the fruit and vegetable waste reached even 33.8%, while the maximal achieved value of the grass waste was only 19.2%. Such obvious differences occurred due to the fact that this experiment was carried out under natural conditions. In the meantime, in another case [23], it was performed under laboratory conditions.

The composition of the researched biodegradable waste also had major influence: this experiment analyzed green waste, while the mentioned author selected mixed fruit and vegetable waste. Having compared the green waste with the admixture of crushed wood of 10, 25, and 50% the conclusion can be drawn that wood suppresses the release of methane. However, the comparison of waste containing 25 and 50% of crushed wood shows that waste with the bigger amounts of crushed wood had highest concentrations. But this occurred after a certain time when a more active process of waste biodegradation started (Fig. 2).

The data obtained by another author, when he added sawdust (in our case crushed wood) to the waste of fruit and vegetables, shows lower values of methane release compared to the waste without the sawdust. Therefore, it can be stated that wood slows down the release of methane.

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Since we are mainly interested in the emission of methane, at the end of this experiment we evaluated the influence of the type of the waste on methane release. In the course of 60 days, with an increase in percentage composition of leaves in the waste, the concentration of methane decreased (when leaves accounted for 25% of the waste, methane emission was 17.2% (111.3 g/m^3), 37.5% – 14.4% (94.1 g/m^3), and 100% – 12.1% (79.1 g/m^3)). The case is different with the grass waste, i.e. when the percentage composition of grass in the total waste increases the concentrations of methane also increase (when grass accounted for 37.5% of the total waste, methane concentration was 14.4% (94.1 g/m^3), and 100% of grass produced a 19.2% (123 g/m^3) methane concentration). The remaining waste, crushed wood, also reduces the emission of methane when its percentage in the total waste composition grows but to a somewhat lower extent compared to the leaf waste (in the case of 10% of crushed wood in total waste the methane concentration is 18.4% (119.1 g/m^3), in the case of 100% – 15.3% (99 g/m^3)). This comparison allows us to draw the conclusion that when wishing to obtain the largest possible concentrations of methane, the largest possible amounts of grass in the total waste have to be used.

When taking the temperatures of internal substrates of the waste, the mean of two measurements was used. Taking into consideration the fact that the experiment was carried out under conditions close to those of the natural environment, the fluctuating ambient temperature influenced the measurement results. The speed of waste degradation for the most part depends on temperature that either accelerates or slows down the process, therefore big leaps inside composts were recorded.

The comparison of temperatures of all wastes, both mixed and uniform ones, shows that with an increase in ambient temperature the temperatures of all the green waste also respectively grows.

The highest temperature was recorded in mixed waste – the mixture of leaves and grass (on the 7th day of measurement it amounted to 40ºC). Within the entire period of measurement the lowest temperature was preserved in the waste of leaves (the minimal temperature amounted to 15ºC on the 51st day of measurement).

On the 19th day, when the ambient temperature fell to 20ºC, the temperature of all wastes also decreased. The same happened on days 37, 41, and 45. Starting from day 49 the temperature of the green waste decreased because the weather also became colder.

Differently from our case, the temperature of the waste researched by the analyzed author was changing differently, even though during the experiment the temperature fluctuations in both these cases were insignificant: in our case temperature in the waste changed from 15ºC to 40ºC, in the author's case – from 12ºC to 34ºC. But waste researched by the analyzed author is characteristic of a steady temperature increase from the beginning of measurements until the end of the experiment while in our case temperatures are distinguished by rather big leaps. In our case, different types of waste had different temperatures, while nearly all the waste researched by the analyzed author had similar temperatures.

Upon having collected the data of the green waste's biogas emissions, they can be evaluated statistically at the end of the experiment. The parameter we are mainly interested in is the dependence of the methane concentration on temperature. Therefore, then, results present the dependences of methane concentration on temperature in all the green wastes. The scattering of the result points is rather big since the experiment was carried out under natural anaerobic conditions.

Based on the dependences of methane concentrations on temperature in all types of waste, it can be stated that with an increase in the waste's temperature, the amount of emitted methane is also respectively growing. This increase directly depends on the type of green waste. Of all the researched waste, the greatest influence of temperature was observed in the waste of the mixture of grass and leaves with a 50% admixture of crushed wood. Within the entire period of measurement the difference between the maximal and minimal values of methane concentrations in the mixture of grass and leaves with a 50% admixture of crushed wood reaches even 14.5%. This was preconditioned by the fact that after a certain time, when the process of degradation of the crushed wood started, the bacteria increasing the methane emissions became more active. The greatest leap in temperature was

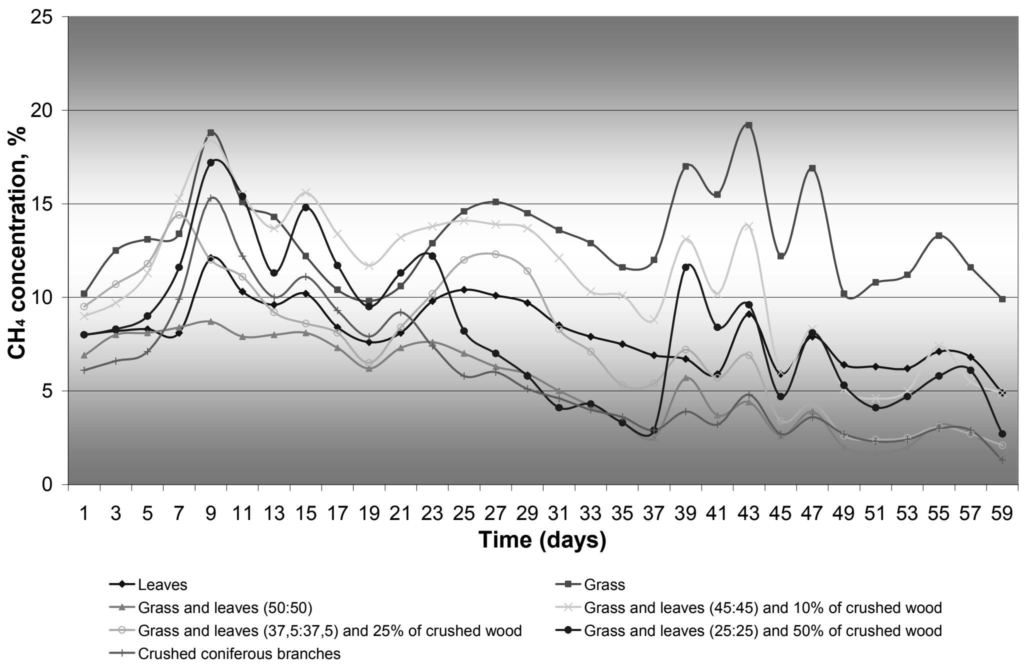

Fig. 2. Methane concentration emissions in all types of green waste

observed in the mixture of grass and leaves (50:50), which amounted to even 21ºC. The strangest thing is that this waste achieved the lowest concentrations of methane, and a difference between the maximal and the minimal values was equal only to 7.1%. In this case the ratio of carbon and nitrogen was unfavourable for bigger concentrations of methane, and the waste of leaves was predominant with the too large amounts of substances containing carbon (Fig. 3).

After analyzing data on biodegradable waste (fruit and vegetable waste) received by another author and using the expression that is convenient for us (i.e. the dependence of methane concentration on temperature), it can be stated that within the entire period of measurement temperature in the fruit and vegetable waste changes by even 22ºC, and methane concentration 29.5%. In the meantime the maximal change of methane concentration in our research is

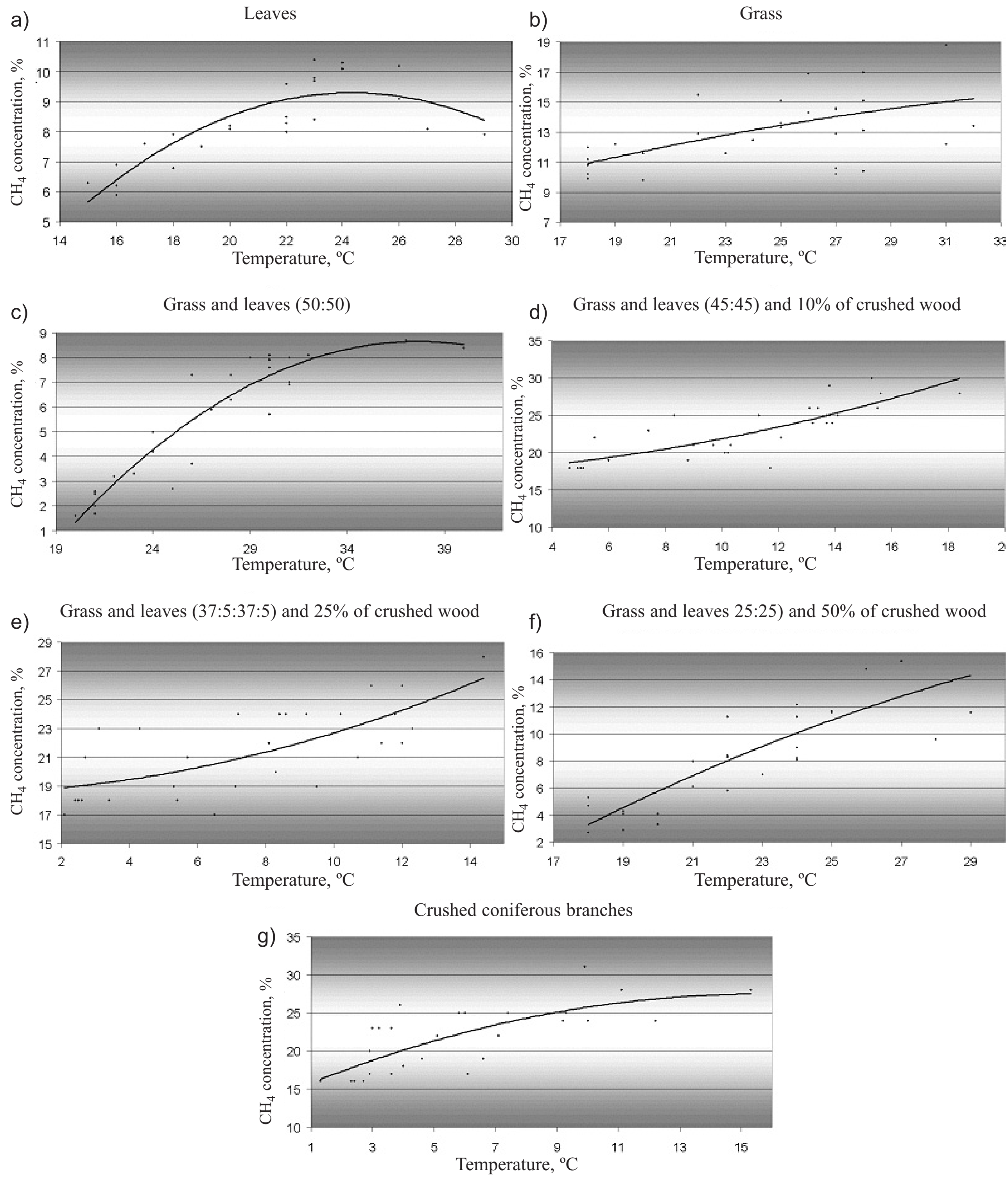

Fig. 3. Dependence of methane in the green waste on temperature: a) leaves, b) grass, c) leaves and grass, d) leaves and grass and 10% crushed wood, e) leaves and grass and 25% crushed wood, f) leaves and grass and 50% crushed wood, g) crushed coniferous branches.

14.5% (in mixed waste). This can be explained by the fact that the fruit and vegetable waste is more quickly decomposed by bacteria than the green waste. At the same time the opinion that the process of biodegradation is slowed down and less methane is emitted when the wood waste is used as an admixture (in the author's case – sawdust) has been confirmed.

Conclusions

1. The crushed grass waste reached the maximum value of methane concentration on the 43rd day of measurements and was 19.2% (123 g/m^3). On the 60th day of measurement the concentration of methane in grass fell to 9.9% (66 g/m^3).
2. Having compared the green waste with the admixture of crushed wood of 10, 25, and 50%, respectively, it can be determined that wood suppresses the release of methane. The highest concentrations of methane were in waste containing 10% of crushed wood (the methane concentration was 18.4% (119.1 g/m^3)).
3. In the course of 60 days, with an increase in percentage composition of leaves in the waste, the concentration of methane decreased (when leaves accounted for 25% of the waste, methane emission was 17.2% (111.3 g/m^3), 37.5% – 14.4% (94.1 g/m^3), and 100% – 12.1% (79.1 g/m^3)). The grass waste, when the percentage composition of grass in the total waste increases the concentrations of methane also increase (when grass accounted for 37.5% of the total waste, methane concentration was 14.4% (94.1 g/m^3), and 100% of grass produced a 19.2% (123 g/m^3)) methane concentration. Crushed wood also reduces the emission of methane when its percentage in the total waste composition grows (in the case of 10% of crushed wood in the total waste the methane concentration is 18.4% (119.1 g/m^3), in the case of 100% – 15.3% (99 g/m^3).
4. The highest temperature was recorded in the mixed waste – the mixture of leaves and grass on the 7th day of measurement reached to 40ºC. Within the entire period of measurement the lowest temperature was preserved in the waste of leaves, with minimal temperature reaching 15ºC on the 51st day of measurement.
5. Based on the dependences of methane concentrations on temperature in all types of waste, it was stated that with an increase in waste temperature, the amount of emitted methane is also respectively growing. This increase directly depends on the type of green waste.

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